Civil Information Modeling Adoption by Iowa and Missouri DOT

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ABSTRACT

Building Information Modeling (BIM) is often perceived as a software tool that is applicable solely for designing and constructing buildings. BIM is more than just a software tool. It is a process that can enhance collaboration between project participants through three dimensional (3D) intelligent models, and it can be effectively used for designing, constructing, operating and managing any type of facilitie including those for horizontal infrastructure. According to a recent smart market report by McGraw Hill, an increasing number of horizontal projects are now taking advantage of a process that is similar to BIM. In order to recognize the special needs of horizontal projects, Civil Information Modeling (CiM) moniker has been adopted by the participants of these projects to describe the process that is equivalent to BIM. Some innovative contractors for horizontal projects are the early users of CiM and some state departments of transportation (DOTs) have also started adopting CiM. Furthermore, some DOTs also take advantage of advanced data collection technologies such as LIDAR that generates surveying data in 3D point cloud form which can be used as basis for 3D design that allows the entire workflow to be in 3D format. This paper presents content the analysis results of interviews conducted with officials of the Iowa and Missouri DOTs who are involved with CiM implementation. It reviews the driving forces, challenges as well as the benefits of using 3D intelligent models throughout the project development process and on into the operation and maintenance stages from DOT's perspectives. It explores current CiM practices while providing a gap analysis that defines what remains to be done in order to fully implement CiM.

INTRODUCTION

Building Information Modeling (BIM) is an emerging technology that has gained increasing popularity among designers and contractors in the civil, architectural, and construction world. According to American General Contractors (AGC) (2006) "Building Information Modeling is the development and use of a computer software model to simulate the construction and operation of a facility. The resulting model, a Building Information Model, is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analyzed to generate information that can be used to make decisions and improve the process of delivering the facility". It is widely accepted that BIM is not only modeling software but also an integrated design and construction process providing a collaboration and communication platform for various parties throughout the project lifecycle (Carmona and Irwin 2007).

Based on the same concept, when BIM is used for horizontal infrastructure projects, another term is applied: Civil Information Modeling (CiM). Other similar terms in the market include Heavy BIM, Horizontal BIM, Virtual Design and Construction (VDC) and 3D Engineered Models for Construction. McGraw-Hill smart market report revealed that almost half (46%) of the firms are applying CiM on their infrastructure projects as of 2012 (increase from 27% in 2010). Furthermore, the report showed that among all users, 67% of them indicated a positive return on investment (ROI) (McGraw-Hill 2012). These findings show that CiM is being adopted at a fast rate by the horizontal construction sector.

The application of CiM for infrastructure projects is less common compared to the usage of BIM on vertical projects (i.e. buildings). A more in-depth understanding is needed for the current CiM application within the heavy civil sector in order to develop a vision for what the full CiM implementation would become. More importantly, the gap between the full implementation of CiM and current practice needs to be identified. The purpose of this study is to explore the current state of CiM implementation as well as the associated benefits and challenges of implementing CiM for the State Department of Transportations (DOT). Iowa DOT and Missouri DOT are chosen to be interviewed for this study since they are in different stages of CiM implementation. Iowa DOT is one of the early adopters of CiM, and Missouri DOT has just started implementing CiM into their business practices. By doing so, it is expected to grasp a broader range of aspects of CiM implementation by the State DOTs.

LITERATURE REVIEW

Unique Properties of Horizontal Projects. Heavy civil construction projects have unique characteristics compared with a typical building construction project. Various land contour, changing site conditions over the long span of a project, existing infrastructure segments and traffic coordination during construction are some of those unique characteristics that impact the design and construction of a new project (Cylwik and Dwyer 2012; Liapi 2003).

Application of 3D Model on Horizontal Projects. The adoption of CiM in the heavy civil sector runs behind the vertical construction sector. However, CiM has started to draw active attention from various project participants including owners, designers and contractors. The major benefits of using CiM include reduced change orders and rework (Parve 2013), more efficient communications (Olde and Hartmann 2012), improved productivity and quality, shortened project duration, and reduced costs (Myllymaa and Sireeni 2013; Cylwik and Dwyer 2012). The implementation benefits are apparent when the following aspects are considered.

Technical Design Checking. By creating all components of a project in 3D, the spatial relationship among various elements can be checked easily so that any conflicts detected can be resolved early in the process (O'Brien et al. 2012). For example, any clashes between underground utilities can be detected within a virtual environment, which would reduce the amount of rework and number of change orders greatly (Olde and Hartmann 2012; Cylwik and Dwyer 2012).

Visualization and Communication. With a 3D model developed, the project team could visualize the geometric configuration of the project in 3D views to better understand various components of a project. Visualization allows engineers to better evaluate design alternatives and perform faster design reviews (McGraw-Hill 2012). When the project schedule is tied to a 3D model, the project team could also visualize the construction sequence and make decisions accordingly (O'Brien et al. 2012). Furthermore, as an interactive tool, the model provides access to various parties to view the animated information for various phases of a project, which would ensure more effective communication between various parties (Liapi 2003).

Construction Planning. A 4D model, which refers to the integration of the scheduling element into the 3D model, plays a critical role in the construction planning phase. The model could be used to select equipment locations, construction methods, and site access approaches. Furthermore, for highway or bridge projects, adding traffic simulations to the model would help designers develop more effective traffic control plans (O'Brien et al. 2012).

Quantity Take-off and Estimates. Quantity take-off and project cost estimates would be more accurate if CiM technology is used. For example, by using a 3D trench model, estimators could easily perform an accurate estimate for amount of cut and fill from existing surface elevations, trench depths, and proposed slopes.

Additionally, laser scanning technology can provide existing terrain conditions in a 3D point cloud which can directly be imported into the CiM software, and this helps to ensure the accuracy of the estimates (Cylwik and Dwyer 2012). According to Jaselskis et al. (2005), the quantities of rock and soil could be estimated with a high level of accuracy by using a laser scanner.

Automatic Machine Guidance (AMG). 3D models can also be uploaded to the computers installed on heavy equipment such as the excavators and graders, so that the operators know how and where they should perform the work (Cylwik and Dwyer 2012). Adoption of AMG improves the productivity and quality of the work performed, and reduces the time and labor required in the field (Peyret 2000).

METHODOLOGY

In order to better understand how CiM for civil infrastructure projects should be implemented, case study approach was adopted for this qualitative research effort. The instructions and procedures for conducting a case study given by Creswell (2013) were used as guidance. Both within-case analysis and cross-case analysis were performed after collecting the interview data.

Research Site and Selection of Participants. According to a report on 3D Engineered Models for Construction by FHWA (2013), Iowa DOT is one of the leading states implementing CiM. Missouri DOT has recently started implementing CiM, and they have plans to move toward full CiM implementation. This situation provided an opportunity for executing the desired cross-case methodology. Thus, the design office director from Iowa DOT and CADD service engineer from Missouri DOT were chosen to be the targeted participants for this study.

Data Collection. Before the formal interview, a pre-structured questionnaire including open-ended interview questions was sent to participants via email. The purposes of the research and confidentiality issues were explained to participants in the email as well as right before the interview on the phone. After obtaining the approval from the participants, telephone interviews were conducted based on their availability. Each interview took about 20-30 minutes.

Data Analysis. After data collection, memo and coding strategies were used to analyze the data according to instructions given by Maxwell (2013). The memo was used to back up analytical thinking during the data collection and analysis process. For each interview, a transcript was created and key statements for each interview question were extracted from the transcript and summarized as coding categories. Subsequently, themes were generated according to identified coding categories. Finally, the coding categories corresponding to a particular theme were associated with each participant.

RESULTS AND DISCUSSION

The major topics investigated in this study include current stage of CiM implementation, use of modeling software, LIDAR technology, organizational structure and workflow adjustments, specifications and guidelines, major challenges, effective strategies, partnerships, benefits of implementing CiM, and legal issues. The major findings for each topic are summarized in Table 1, and the highlights of these findings are discussed below.

In terms of the current stage of CiM implementation, it appeared that neither DOTs are implementing CiM to its full extent. Iowa DOT uses LIDAR data to create 3D models for the planning and design phases (LIDAR data is available for the entire state of Iowa), and model all their projects in 3D. Missouri DOT uses LIDAR data for surveying and mapping (entirely outsourced), and recently began to use 3D models for design purposes, only for large expansion projects for now. As for modeling software, Iowa DOT uses Bentley Corridor Modeler, and Missouri DOT uses Power GEOPAK (an older version) and plans to upgrade to a new generation modeling software. Neither DOTs has made any progress on using CiM for asset management tasks. Both states provide electronic files to contractors during pre-bid period. However, 2D plans are still the governing documents for legal purposes in both states. Neither DOTs has made any changes to their organizational structure during the implementation of LIDAR and 3D modeling, however both DOTs have made some adjustments to their design workflow. No partnerships were formed with other agencies and/or contractors when implementing CiM, reported by both DOTs, instead, they only asked for contractors' input. So far, Iowa DOT has developed a specification for contractors and Missouri DOT has created their own internal design guidelines for CiM implementation.

Various challenges were addressed by the participants. For Iowa DOT, lack of guidelines or best practices, reluctance of people to embrace new technologies or workflows, and lack of in-house expertise were the biggest challenges when adopting CiM into their workflows. When they first started 3D modeling, no standard file format was available until later on TransXML was adopted. On the other hand, the most prominent challenges regarding CiM implementation for Missouri DOT include: funding and policy issues, lack of technical infrastructure (storage, bandwidth, and data accessibility), lack of in-house expertise, incompatible software and hardware, and challenges meeting contractor needs with regard to data exchange formats.

Based on previously identified challenges, various strategies were adopted by both state DOTs that turned out to be effective. When Iowa DOT employees first implemented CiM, they worked with equipment manufacturers and contractors with relevant experience to adjust their workflow, and they also (as mentioned previously) adopted TransXML as a standard data exchange format. On the other hand, Missouri adopted LandXML as a standard data exchange format. The participant from the Missouri DOT also addressed three approaches that the agency has adopted to overcome problems during CiM implementation, including (1) providing guidance and training to data producers; (2) convincing participants of the added value of modeling/CiM; and (3) engaging senior management and other data users.

Both state DOTs reported various benefits from the implementation of CiM. The participant from Iowa DOT described those benefits as increased contracting efficiency, cost savings, and better design. The participant from Missouri DOT described benefits as the availability of a multi-purpose model that can be used by various parties, better collaboration and problem detection, more innovative solutions, reduced risks and lower bid prices, and more clarity with regard to design intent.

Finally, participants were asked whether their organization had encountered any legal issues during CiM implementation. It appeared that this is not a concern for Iowa DOT since the 2D paper plans are still the dominating contract documents; however, it is acknowledged that there would likely be legal issues later on when the agency executes its plan of switching to electronic file delivery. On the other hand, Missouri DOT participant stated that they had encountered some legal issues such as who should make changes to the model and how those changes should be validated.

Table 1. Findings from the Interviews with Iowa DOT and Missouri DOT

Themes	Iowa DOT	Missouri DOT
Current Stage of CiM Implementation	Uses LIDAR data to create 3D model. LIDAR data exists for the entire state	Uses LIDAR data for surveying and mapping. Just starts to use 3D for design
	Model is not used for asset management	Model is not used for asset management
	Provides electronic files to contractors pre-bid	Provides electronic files to contractors pre-bid
	Models all projects in 3D	Only models large corridor expansion projects in 3D
	2D plans are governing documents	2D plans are governing documents
Modeling Software and LIDAR Scanner	Bentley Corridor Modeler	Power GEOPAK, and will soon upgrade to a new modeling software
	Static LIDAR scanner	Terrestrial LIDAR scanner
Organizational Structure and Workflow Adjustments	No organizational structure changes	No organizational structure changes
	Change of workflow, but was not discussed in detail	Change of workflow (review typical cross sections--design model--create cross sections, print plan sheets after the design is complete)
Specifications and Guidelines	Own specification for contractors	Own guidelines for designers
	A matrix is under development for consultants	Plan to develop guidance for construction inspection and payment of quantities
Major Challenges	Lack of guidelines/best practices when started	Funding and policy issues
	Reluctance of people regarding new technologies or workflows	Lack of technical infrastructure (storage, bandwidth, data accessibility)

Themes	Iowa DOT	Missouri DOT
	Lack of in-house expertise	Lack of in-house expertise
	No standard data exchange format during initial implementation stage	Incompatible software and hardware
		Lack of investment and training
		Challenges meeting contractor needs with regard to data exchange formats
Effective Strategies	Adopted standard data exchange format (Trans XML)	Adopted standard data exchange format (LandXML)
	Worked with equipment manufacturers and contractors with experience to adjust the workflow	Provided guidance and training to data producers
		Engages senior management and other data users
		Convinces participants of the added value
Partnership	No	No
Benefits of Implementing CiM	Increased contracting efficiency	Multi-purpose model used by various parties
	Cost savings	Innovative solutions, improved collaboration and problem detection
	Better design	clarity in design intent
		Reduced risks and lower bid prices
Legal Issues	Currently not a concern	Who should be allowed to make changes to the model and how to validate

CONCLUSIONS AND RECOMMENDATIONS

Based on the findings of this case study, it is concluded that both Iowa and Missouri DOTs have put considerable effort into transitioning from 2D plans to 3D modeling, and they plan to continue moving forward toward the full CiM implementation. LIDAR technology has been adopted by both DOTs to collect more accurate survey data in a faster manner, and the collected data has then used to create 3D models. Both state DOTs are transitioning, with each of them developing their own guidelines or specifications as well as a standard file transfer format, to assist in creating and sharing models with other project participants. Both state DOTs provide electronic files including 3D models to contractors, but 2D plans are still the governing contract documents in both states.

Recommendations for Future Practice and Research. The ideal scenario would be for project participants to use the model for the entire facility lifecycle from the initial planning through design, construction, and on into operational and asset management phases in order to ensure that the information is refined, and accurately delivered for each phase. Overall, CiM implementation for operations and asset management is not a common practice in the horizontal construction world. This issue should be investigated and addressed through enhanced collaboration among researchers, industry practitioners, and software vendors.

Future research should explore how to create and use as-built models for asset management effectively. More case studies should be conducted on CiM-implemented projects to investigate overall workflow and effective strategies for resolving the real-time issues. In addition, studies could be conducted with the states that have already included electronic files (possibly with 3D models) in their contracts to determine how they have addressed the actual legal issues that they have encountered and the strategies that they have adopted to prevent such issues.

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